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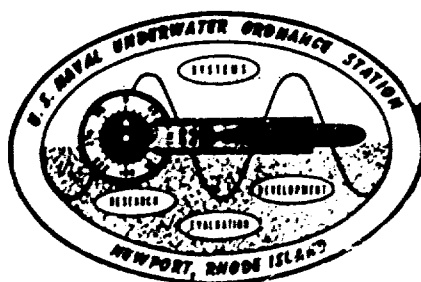
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A SAMPLE TEST EXPOSURE
TO EXAMINE CORROSION
AND FOULING OF EQUIPMENT
INSTALLED IN THE DEEP OCEAN



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UNDERWATER ORDNANCE STATION
NEWPORT, RHODE ISLAND

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NEWPORT, RHODE ISLAND

TECHNICAL MEMORANDUM

A SAMPLE TEST EXPOSURE TO EXAMINE
CORROSION AND FOULING OF EQUIPMENT
INSTALLED IN THE DEEP OCEAN

Prepared by *S. Milligan*
S. Milligan

November 1962

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WEPTASK Assignment No.
RUTO-BS-000/219 1/SF09-90-322

FOREWORD

The development of underwater sound tracking systems for use in deep water has posed many new problems, one of which concerns the environmental effects of marine growth and corrosion on the components of the instrumentation. As technical direction agency for underwater tracking systems, the U. S. Naval Underwater Ordnance Station is vitally interested in these effects.

Test samples representative of materials composing various tracking arrays are being exposed to deep sea environment in the Tongue of the Ocean (TOTO), Bahama Islands, on a continuing basis.

This report concerns an exposure of array samples made during the period of 5 April 1962 to 25 July 1962.

The work was accomplished under WEPTASK number RUTO-BB-000/219 8/SF09-90-322.

SUMMARY

Fouling and corrosion tests are being conducted at deep sea depths in the Tongue of the Ocean (TOTO), Bahama Islands, to provide information needed in selecting materials for use in underwater installations.

Test samples representative of these materials were exposed at a depth of approximately 5100 ft in TOTO from 5 April 1962 to 25 July 1962.

Upon retrieval, there were no signs of fouling or of marine borer action in any of the samples. Certain alloys of the aluminum samples showed considerable corrosion. Small blisters were apparent in localized areas of the coated low carbon steel panel, although extensive corrosion had not taken place. Conductor cables, except for the sample prepared without the outer covering of jute, were not corroded. None of the plastic jackets of the conductor cable samples were cracked, although the polyethylene jacket of the anchor strength wire rope sample did show splitting in several places.

It is recommended that:

1. To avoid corrosion all metal structures designed for installation in deep water be coated or covered with pliable plastic material in order to take advantage of possible pressure sealing effects.
2. The use of anti-fouling compounds at the test depth be avoided unless future tests show the necessity for such coatings when materials are directly in contact with the bottom.
3. Considerable care be taken to select the proper jacketing material of the anchor strength wire rope to insure against splitting under the environmental stresses encountered in deep water.

ACKNOWLEDGEMENT

The courtesy of the Marine Corrosion Section of the Metallurgy Division of the U. S. Naval Research Laboratory is appreciated for permission to allow samples to be installed on their corrosion test vehicle.

INTRODUCTION

Components of sound monitoring systems are continuing to be exposed in TOTO (Tongue of the Ocean, Bahamas), to accumulate knowledge on the effects of deep sea environment.

One phase of this effort involves the exposure, for various periods, in TOTO of samples representative of underwater sound installations for which the Naval Underwater Ordnance Station (NUOS) has technical direction.

The U. S. Naval Research Laboratory (NRL) is carrying out an extensive general program of corrosion studies at deep depths in TOTO in which a variety of materials are being exposed and examined⁽¹⁾. Through the courtesy of NRL some NUOS test samples are undergoing exposure on the NRL specimen test vehicle. On 25 July 1962, samples were retrieved, which had been exposed since 5 April 1962 at 24°55.0'N, 77°48.2'W at a depth of approximately 5100 ft (just above the bottom).

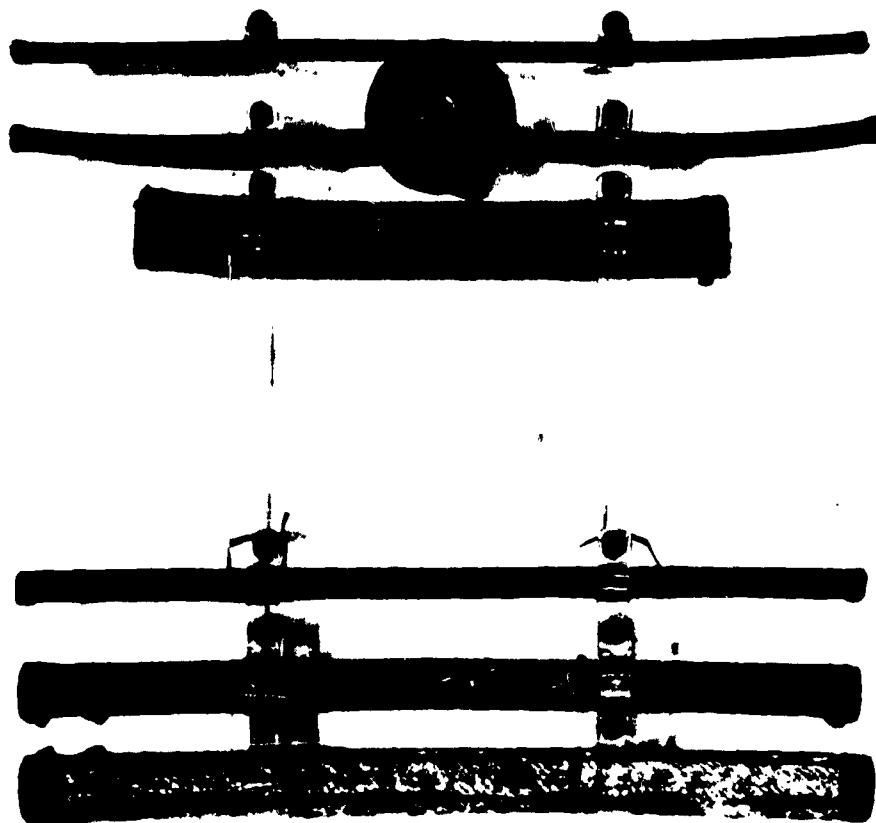
DESCRIPTION OF SAMPLES

The samples consisted of:

1. A 6 inch x 12 inch x 1/4 inch panel of plexiglas on which were mounted six cable samples and a molded piece of polyurethane rubber (figure 1).
2. An 18 inch length of polyethylene-jacketed steel wire rope (figure 2).
3. A coated steel panel (figure 3).
4. Two 6 inch x 12 inch x 1/4 inch panels of molded phenolic board containing a number of stressed and unstressed aluminum samples (figure 4).

Conductor Cable Samples

The cable samples mounted on the plexiglas panel consisted of a 12 inch length of caged, high density, polypropylene-covered single conductor cable representative of the caged conductor cable installation of the Random Base Line Array; a 12 inch length of balanced, shielded-pair, high density, polyethylene-covered conductor cable (one of six in the cable structure of the communications cable of the Rigid Base Line Array); an 8 inch length of the completed communications cable of the Rigid Base Line Array, with an outer covering of tightly woven nylon braid saturated with asphalt; a 12 inch length of three twisted pair, high density, polyethylene-covered conductor cable of the Taut Wire Array, without armor or jute; a 12 inch length of three twisted pair, high density, polyethylene-covered conductor cable of the Taut Wire Array, with double armoring of galvanized steel wires; a 12 inch length of



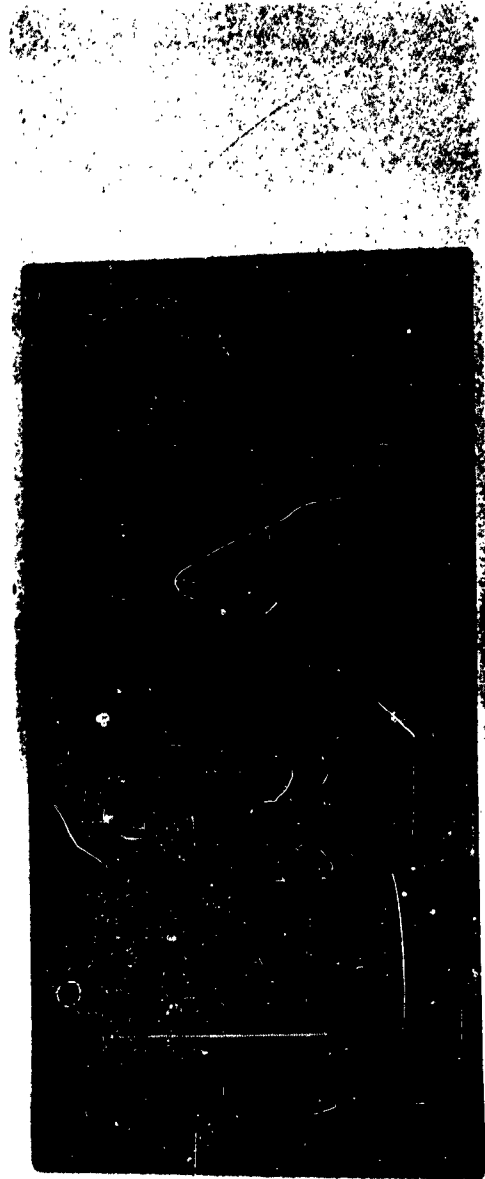
Cables and Polyurethane Rubber Samples
After Exposure

Figure 1



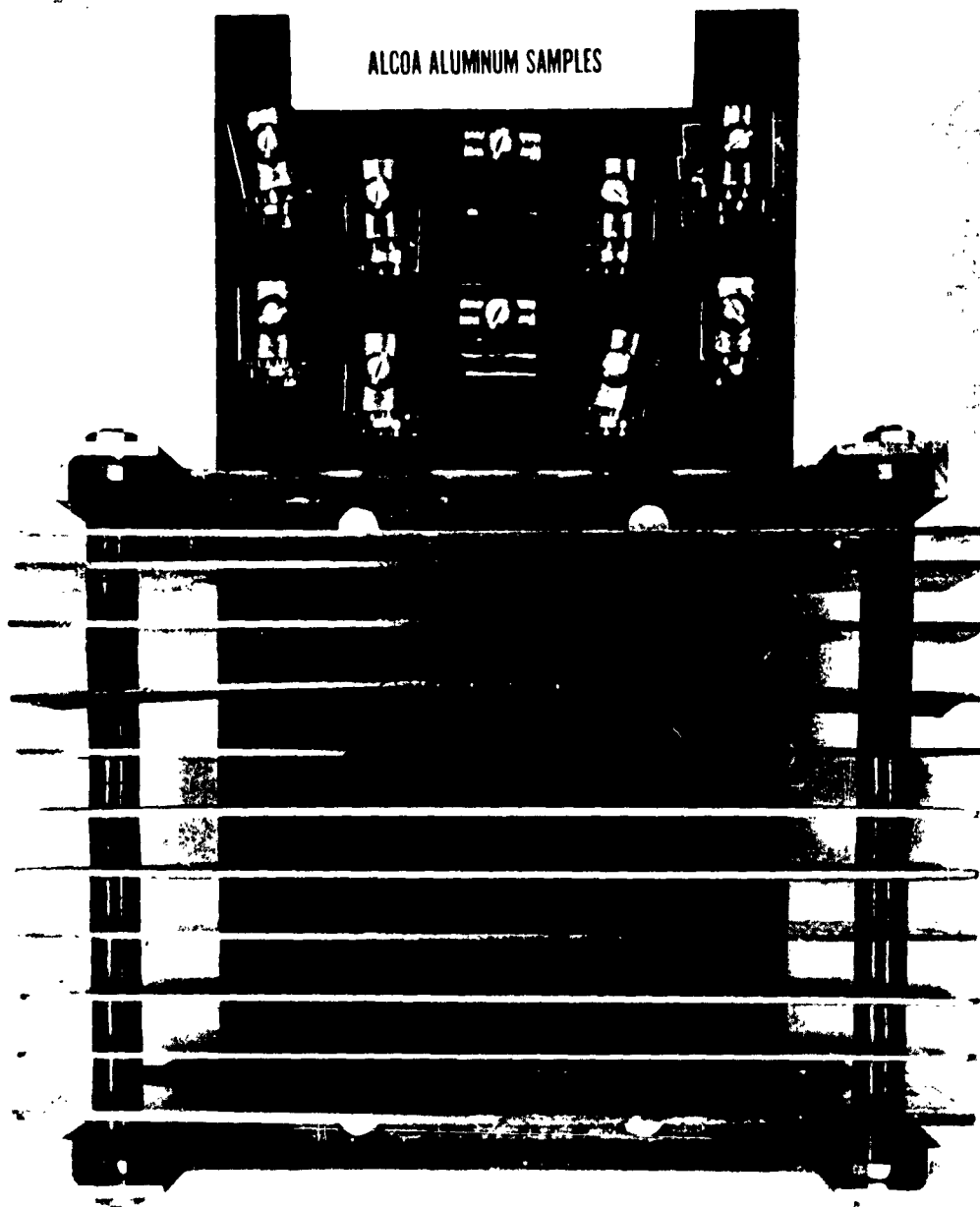
Polyethylene Jacketed Steel Wire Rope Sample
After Exposure

Figure 2



Coated Steel Panel Sample
Prior to Exposure

Figure 3



Aluminum Samples Before Exposure

Figure 4

three twisted pair, high density, polyethylene-covered conductor cable, with double armoring of galvanized steel wires and an outer covering of jute which had been coated with a hot melt anti-fouling cuprous oxide type compound.

Polyurethane Molded Rubber Sample

This sample mounted on the rear of the plexiglas panel is a unit designed as a hydrophone mounting pedestal on the Rigid Base Line Array.

Polyethylene-Jacketed Wire Rope Sample

This sample was one of three undergoing exposure and was removed from a supporting panel of molded phenolic board. It is a sample of the medium density, polyethylene-covered, steel wire rope strength member used at the bottom of the Taut Wire Array between the anchor and the conductor cable.

Coated Steel Panel

This sample consisted of a 6 inch x 12 inch x .125 inch low carbon (QQ-S-636) steel panel coated with finishes used on the steel hydrophone support structure of the Rigid Base Line Array. The panel, after surface grinding, was degreased and coated with one coat of Zinc Chromate Yellow, High Alkyd; one coat of Day Glo White Primer; one coat of Day Glo Blaze Orange; and one coat of Day Glo Filteray clear finish.

Aluminum Samples

The aluminum samples consisted of 3/4 inch diameter, short transverse C-ring specimens of various alloys under different degrees of applied stress and 0.064 inch x 3 inch x 9 inch panels of various alloys.

METHODS OF SECURING SAMPLES

The cable samples were secured to the plexiglas panel board with ethyl cellulose clips and nylon bolts, washers, and nuts. Nylon lacing tape was used to additionally secure the heavier cable samples. Cable ends were sealed with two coats of Minnesota Mining and Manufacturing Company EC524 cement. The strength wire sample was secured to the backing panel of molded phenolic board with stainless steel U bolts. The aluminum samples were also secured to backing panels of phenolic board with aluminum bolts.

ENVIRONMENTAL CONDITIONS

The following data indicate the environmental conditions close to the test location. These data were not obtained at the time of the exposure.

However, little variation has been found to occur between readings taken at various periods at this depth. They should, therefore, be representative of conditions which existed during the period of the test.

Sample Depth (M)	T°C	Salinity ‰	Spec. Grav. σ _t	O ₂ (ml/l)
1500	4.12	35.00	27.80	5.26

RESULTS

Examination of the samples (see figure 5) immediately upon retrieval showed them to be very clean. There were no signs of fouling growth. Close examination showed no signs of marine boring action in any of the plastic covered cable samples.

None of the plastic jackets of the conductor cable samples were cracked.

The polyethylene jacket of the anchor strength wire rope sample of the Taut Wire Array did show splitting in several places (see figure 2).

The stainless steel bolts used to secure the wire rope sample to the backing panel of phenolic board were severely corroded around the screw threads. One bolt had corroded completely away and was missing. This was attributed to crevice corrosion under the nylon nuts, which is known to proceed freely on stainless steel when immersed in sea water.

The sample of conductor cable of the Taut Wire Array which had been prepared without the outer covering of jute in order to expose the galvanized steel armor wire directly to the water, while having a clean appearance immediately on removal from the water, rapidly rusted in the air. This indicated that the zinc galvanize had become depleted, exposing the steel to corrosive effects. Analysis of the outer armor wire for zinc content, after removal of loose corrosion products, showed the outer armor wire to contain less than 10% of the original zinc coating. The zinc apparently was randomly dispersed as indicated by the extensive rusted appearance. The inner armor wire showed no evidence of rust but showed considerable zinc corrosion products. Analysis of the inner wire showed approximately 50% of the original zinc remaining. The zinc of the inner armor wire was evenly corroded, which was apparently due in part to the anti-corrosive slushing compound applied to the inner armor wire during manufacture.

The jute covered sample of the Taut Wire Array conductor cable visually was in excellent condition, with no loss of jute apparent. The color of the hot melt, anti-fouling impregnant of the jute indicated that the anti-fouling compound had performed in a satisfactory manner. Removal of the jute disclosed that no zinc or iron corrosion had occurred in either the outer or inner armor wire. Although the hot melt black tar coating which



Cable Samples Immediately After Retrieval

Figure 5

had been applied to the outer armor cable prior to jute application during manufacture, did not adhere to the galvanized surfaces, it apparently combined with the jute to give an excellent seal over the armor wires. Determination of the amount of zinc coating of the outer and inner armor wires showed that no loss of zinc had occurred in either case.

The polyurethane pedestal hydrophone mount sample appeared to have undergone no change. Size, weight, and hardness measurements showed no differences between the initial measurements before exposure.

The coating system on the low carbon steel panel, representative of the coatings used in the Rigid Base Line Array, while generally intact, gave some small evidence of deterioration (see figure 6). Small blisters were apparent in localized areas, and the paint had become somewhat brittle and friable at the blistered areas. Extensive corrosion had not proceeded.

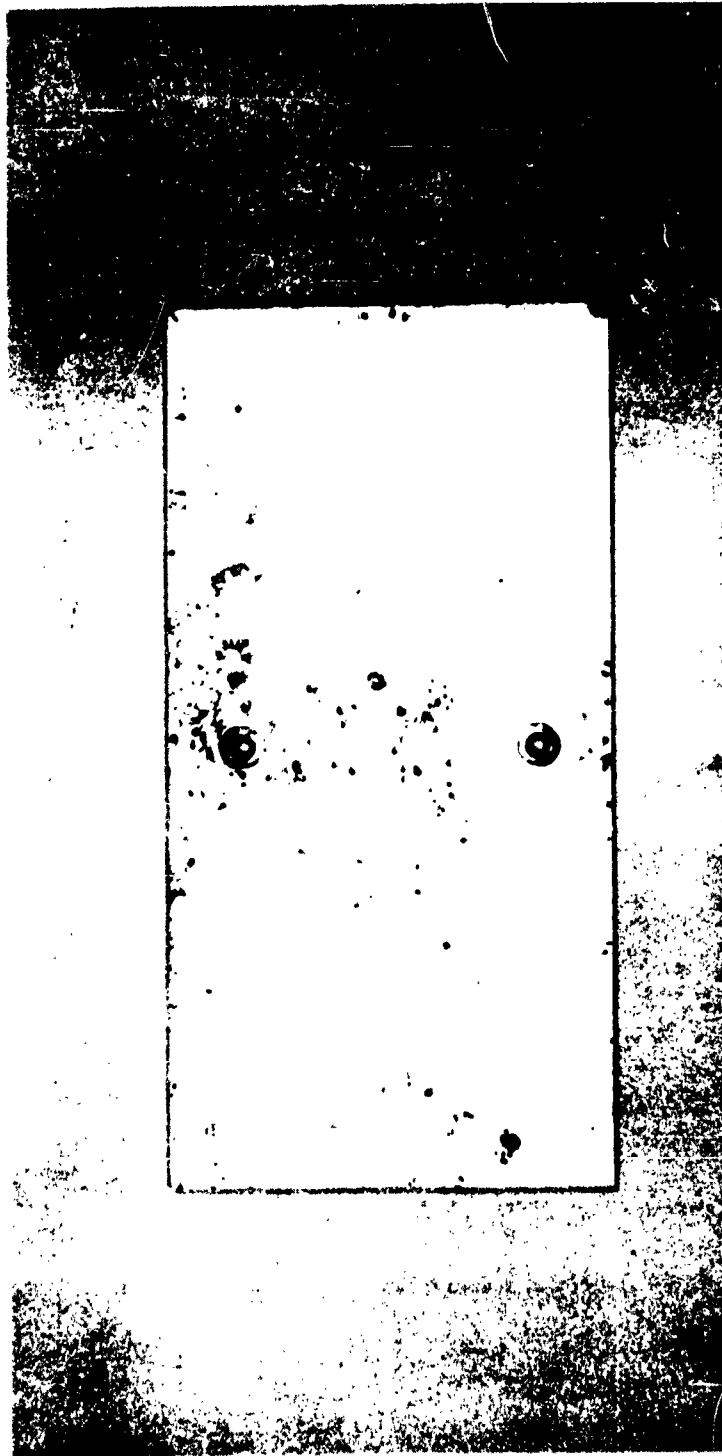
Certain alloys of the aluminum samples showed considerable aluminum oxide corrosion products (see figure 7). These samples were forwarded to the Aluminum Corporation of America research laboratories for evaluation.

DISCUSSION

Photographs and bottom sample analyses have given evidence that considerable marine life exists at the bottom in TOTO. However, the lack of marine growth and absence of marine borer action indicate that such action will not occur on installations near the bottom at the test depth of 5100 ft. At least no attack was experienced on any of the samples during the particular exposure period. Continuing tests may disclose such action.

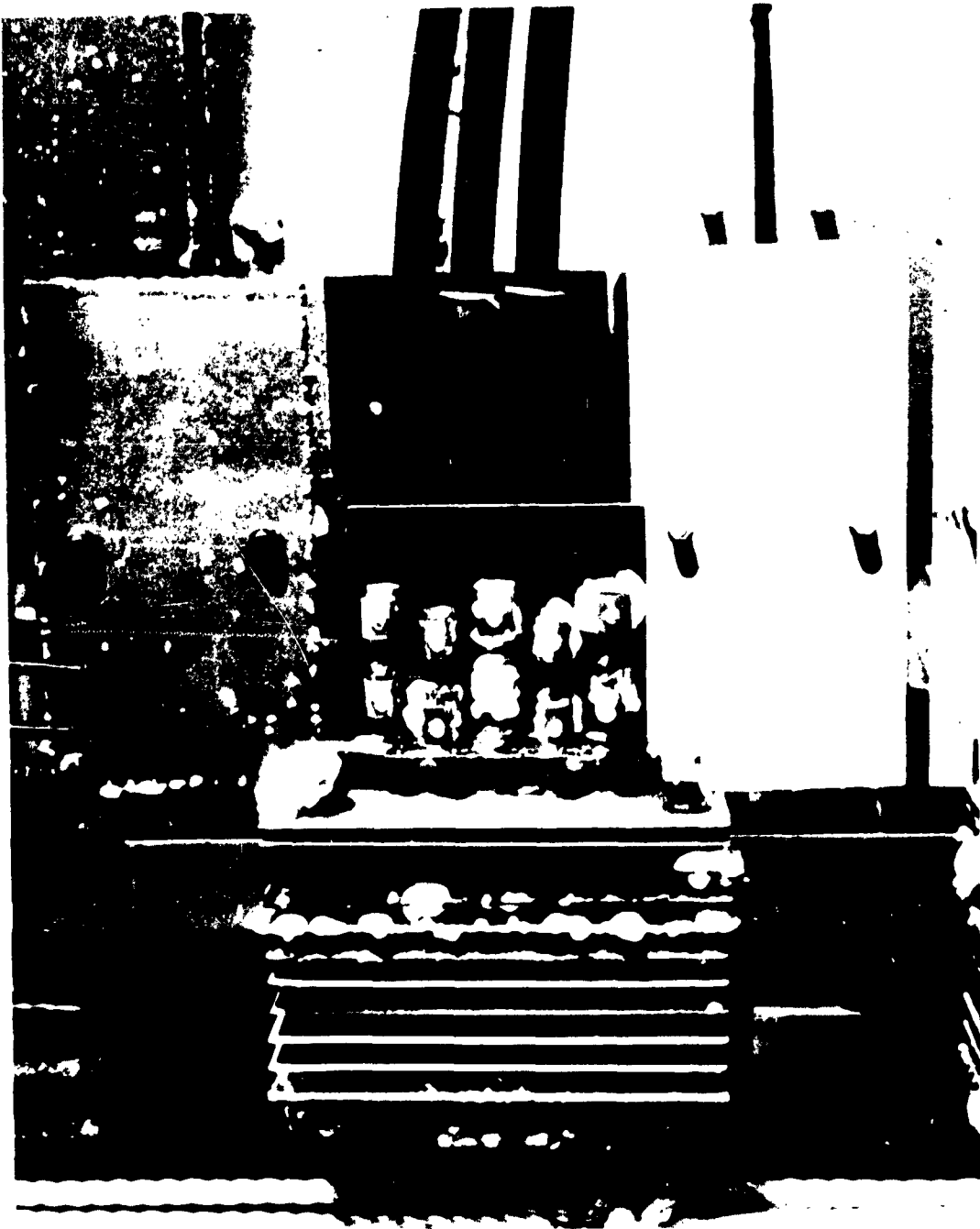
One factor which seems important in protection against corrosion of metals is the high pressure (approximately 2500 psi) existent at 5100 ft depth. The appearance of the armor strength wires of the Taut Wire Array cable indicated that no water had been in contact with the galvanized steel armor wire. On removal of the jute wrapping, it appeared that the combination of jute and tar had formed a continuous cover which the high pressure had forced tightly over the cable armor. This process apparently provided complete sealing and prevented water from entrance to the metal. If such sealing occurred, then the effect of cracking of the polyethylene jacket of the Taut Wire Strength Cable would be restricted to the small surfaces exposed by the cracks. The high pressure, by forcing the polyethylene jacket tightly against the wire surfaces and the wire strands tightly against each other, should prevent water from diffusing to any distance from the metal surface close to the cracks.

Protective films by being forced tightly against the metal surface should also offer better protection than in areas of low external pressure. However, the film must be of sufficient thickness, continuity, and



Coated Steel Sample Panel
After Retrieval

Figure 6



Aluminum Samples Immediately After Retrieval

pliability to prevent local contact with the surface, such as through pinholes. Rubber or plastic base finishes possessing good adhesive qualities and a high degree of flexibility, which will allow ready molding by the water pressure to an underlying metal surface without cracking, suggest themselves as satisfactory coating materials for metals under the high pressure experienced at great depths. Apparently, pressure may have been an important factor in preventing corrosion of the Taut Wire Array conductor cable samples in a previous exposure⁽²⁾. In the previous test, corrosion of galvanized armor wires of the Taut Wire Array samples was not noted at depths below 640 ft but was noted above this level. It may well be that such cables should be constructed to take advantage of pressure effects for protection of metal surfaces. In order to obtain maximum protection against metal corrosion, construction of an installation designed for exposure from near the surface to the ocean bottom should perhaps be different at shallower depths than at deeper depths.

CONCLUSIONS

Continuing tests may disclose unexpected results. However, based on this exposure test, the following conclusions are drawn:

1. The method of attaching cable samples using ethyl cellulose clips, nylon washers, and bolts is satisfactory.
2. At 5100 ft sealing of the open cable ends with Minnesota Mining & Manufacturing Company EC524 cement is a satisfactory method of preventing water contact with the interior of the cable sample.
3. The plastic jacketing material of high density polyethylene in all conductor cable samples stood up well in the unstressed condition.
4. The polyethylene jacket of the anchor strength wire rope is unsuitable for the intended purpose since the cold temperature and high pressure of the environment at 5100 ft cause cracking.
5. No fouling or marine life attack occurs on the exposed materials at 5100 ft (just above the bottom).
6. Corrosion of exposed metals occurs readily. Paint films offer good protection but must be sufficiently thick to give a continuous film without pinhole effects.

RECOMMENDATIONS

It is recommended that:

1. To avoid corrosion, all metal structures designed for installation in deep water be coated or covered with pliable plastic material in order to take advantage of possible pressure sealing effects.

2. The use of anti-fouling compounds at the test depth be avoided unless future tests show the necessity for such coatings when directly in contact with the bottom.

3. Considerable care be exercised to select proper jacketing material of the anchor strength wire rope to insure against splitting under the environmental stresses encountered in deep water.

REFERENCES

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- (1) L. J. Waldron, M. H. Peterson, B. W. Forgeson and B. F. Brown. "Abyssal Corrosion and Its Mitigation Part I, Details of Pilot Test Exposure." NRL Memorandum Report 1282, March 1962

Naval Underwater Ordnance Station

- (2) S. Milligan. "Effect of Deep Ocean Environment on Underwater Installations." TM No. 271

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It is recommended that:

1. To avoid corrosion all metal structures designed for installation in deep water be coated or covered with pliable plastic material in order to take advantage of possible pressure sealing effects.
2. The use of anti-fouling compounds at the test depth be avoided unless future tests show the necessity for such coatings when materials are directly in contact with the bottom.
3. Considerable care be taken to select the proper jacketing material of the anchor strength wire rope to insure against splitting under the environmental stresses encountered in deep water.

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